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(54) Title: METHOD AND APPARATUS FOR PROCESSING WASTE

(57) Abstract: Organic waste is mixed and shredded in a mixer shredder (16) and composted in a thermophilic composting system (32). A portion of the compost as used as feedstock for a vermiculture system (46) to produce worm castings. The compost and castings can be used separately or blended. Liquid wastes may be treated in a digester (26) by aerobic or anaerobic digestion, and the resulting sludge fed to the vermiculture system (46).

Method and Apparatus for Processing Waste

This invention relates to a method and apparatus for processing waste. In particular, this invention relates to a method for converting the organic portion of the wastestream into a variety of useful products, including a quality growing medium; and to apparatus for putting this method into practice.

Every year, one thousand million tonnes of putrescent waste are dumped in landfill sites in Europe alone. This has a damaging impact on the environment. EU legislation implementing enforcement of recycling targets has recently been put in place. There is thus an urgent requirement for a feasible and cost effective system for achieving these targets. Since at least 40% of the municipal wastestream is organic this proportion of the wastestream has the potential for conversion into useful products such as compost and soil amendment.

Currently, the best practical environmental option (BPEO) for waste treatment is incineration. However, incineration recovers only a fraction of the energy contained in organic material; it produces toxic ash; and the variable nature of the waste needing treatment causes serious operational problems in an incinerator.

Thermophilic composting is a more attractive option. However current thermophilic composting practice necessitates utilising large areas of land for heaping waste out of doors, in long windrows. Variations in weather conditions affect the waste making the process of composting slow, and its product inconsistent. There is a requirement to turn the heaps periodically, and this is achieved by using expensive diesel fuelled machinery. Windrow composting produces gaseous and leachate emissions, which cause adverse environmental impact. The products of such composting are of inconsistent and unpredictable quality which, whilst usable, are not very suitable for sale as compost, and therefore are of limited value.

An alternative thermophilic composting practice is to utilise in-vessel thermophilic systems. However, to date many of these are mechanically and electronically complex. They are mostly batch processes; are capital intensive; and require considerable energy input.

The problem of converting organic waste economically into a usable product has led to the development of the use of worms to recycle organic material. In this method, worms in a worm bed, a support structure supporting a layer of biodegradable organic material, are fed biodegradable organic waste material (BOWM) to produce digested biodegradable organic material, known as castings. These castings are exceptionally good soil amendment. This process can take place in an organic digester.

An effective 'high-tech' continuous flow vermi-organic digester comprising a worm bed is described in CA2170294 (Eggen). This digester comprises a ventilated enclosure containing a grating system which supports a layer of BOWM, which provides an environment for an immense biomass of worms (composting worms or brandlings). From their introduction to the BOWM, the worms feed and begin to produce castings. This worm biomass is capable of consuming its own weight of suitable waste material per day.

The intensity of biological material in the surface layers of the bed requires these layers of the bed to be routinely loosened to allow for aeration to the entire worm population. There is also a misting system to ensure that the surface layers do not dry out, and a system of blowers controlled by temperature sensors to avoid overheating.

A constant supply of BOWM is introduced to this mix of worms, BOWM and castings. As the worms digest the BOWM they naturally migrate upwards in search of more food, separating the mix as a consequence - a worm-free layer of castings forms on the grating under the worm-containing BOWM.

This organic digester also comprises a raking system operable to loosen this bottom layer of castings from the mix for removal. The castings can then be removed for use as compost or soil enrichment. The organic digester further comprises a thermostatically controlled ventilation system to maintain an optimum operating temperature in the worm bed, and to regulate moisture. This ensures the maximum consumption of waste and the production of material of consistent and repeatable quality.

However, although this organic digester is ideal for up to one metric tonne of waste per day, it would require a digester of unmanageable scale (or a large area of smaller digesters) for larger scale operations such as those faced by municipal waste systems.

The succession of recent health scares including CJD, E. coli, salmonella, and foot and mouth disease have led to legislation requiring a certain degree of pathogen kill in the food/animal waste processing technology.

There is thus a requirement for a composting process having minimal environmental impact and capable of processing large volumes of waste in a small area, and preferably being capable of killing pathogens in the waste.

According to the present invention there is provided a method for processing organic waste, in which waste is treated by microbial decomposition, and at least a proportion of the resulting treated waste is further treated by vermiculture in worm bed.

The microbial decomposition may comprise thermophilic composting, or aerobic or anaerobic digestion, or both.

From another aspect, the invention provides compost produced by the foregoing method, most preferably compost mixed with 1 - 10% of worm castings.

A further aspect of the present invention provides apparatus for processing waste comprising microbial decomposition means for receiving waste and producing microbial decomposition therein, vermiculture means receiving organic material and supporting a population of worms feeding upon said material to produce castings, and transfer means for transferring a selected proportion of treated material from the microbial decomposition means to the vermiculture means.

Preferred features and advantages of the invention will be apparent from the following description and claims.

Embodiments of the invention will now be described by way of example only with reference to the drawings in which:

Fig 1 is a schematic diagram of the method of an embodiment of the present invention;

Fig 2 is a schematic illustration of one form of composter which can be used in the present invention; and

Fig 3 is a schematic illustration of an alternative composter.

Referring to Fig 1, this method uses the steps of treating organic material using selected micro-organisms to produce compost and then treating the compost in a variety of ways, including introducing part of the compost to a worm bed to produce digested biodegradable organic material known as castings.

The apparatus and system of Fig. 1 treats a number of organic waste streams 10, 12, 14. These waste streams are separated at source and may comprise green matter, catering slops, sewage sludge, manure, abattoir waste, poultry waste, fish waste, seaweed, household organic waste, brewery/distillery waste, paper, cardboard, supermarket waste, and other biosolids. Wastes which are substantially dry, such

as waste streams 12 and 14, are passed directly to a shredding and mixing machine 16.

Wastes which have a significant liquid content, such as waste stream 10, are first shredded by a shredder 18 and then treated in a moisture modification apparatus 20 (which may be, for example, a filter, belt press or centrifuge) to produce a solid stream 22 and a liquid stream 24. The solid stream 22 passes to the mixer/shredder 16. The liquid stream 24 is passed to a digester 26 of known type for aerobic or anaerobic digestion to produce a clarified liquid 28 which is discharged to drain or watercourse, and sludge 30 which is used as described below.

Optionally, bioaugmentation as indicated at 50 may be applied to the digester 26 and/or to the shredder/mixer 16, bioaugmentation being the addition of micro-organisms which will be beneficial to the breakdown of the waste material. Treating organic material using selected micro-organisms (bioaugmentation) encourages immediate initiation of the degradation of the material. Encouraging degrading in this way ensures that the method proceeds optimally.

The mixer/shredder 16 reduces the organic waste to a small size and mixes the various waste streams together. An important factor in the rapid breakdown of waste by thermophilic material has been found to

be the shredding of paper, cardboard and green material right down into its constituent individual fibres. The shredder blades should rotate at a speed sufficient to achieve this. This ensures that extensive surface areas of material are exposed to bacterial action, and by ensuring optimal conditions in an in-vessel system the composting process is both very rapid and consistent.

The resulting material passes to a thermophillic composting system 32. Optionally, nitrogen sources and/or bulking agents may be added at this point. Alternative forms of thermophillic composting system which may be used at 32 are discussed below. The resulting compost passes through a screen 34 to be separated into a coarse fraction 36 and a fine fraction 38.

The coarse fraction 36 is passed to a first curing store 40. A selected proportion of the fine fraction 38 is passed to a second curing store 42. The compost is held in the relevant curing store for about four weeks to cure or fully stabilise before being packed or transported for use. An alternative is to pack immediately in porous sacks, which enable sufficient air to penetrate the product to allow for the final bacterial and fungal activity which will render the product stable.

The remaining portion of the fine fraction 38 of the compost is passed to a shredder 44 which reduces the

compost further in size to a very fine fibrous form, which is fed to a vermiculture apparatus 46. The digested sludge 30 is also fed to the vermiculture apparatus 46. The vermiculture apparatus 46 is preferably a self-contained, compact, highly automated apparatus of the type describer in CA 2170294 (Eggen); however, other types of vermiculture apparatus may be used in the present invention.

Feeding the vermiculture apparatus with material which has undergone shredding and thermophilic composting has a number of advantages. The feedstock has already had pathogen kill and the destruction of all weed seeds. In addition, the rapid action of the thermophilic bacteria has increased the palatability of the fraction for the worms by breaking down the material, and in particular by starting to break down the tough fibrous material, which speeds up the vermidigestion phase and raises the production rate of castings.

The castings which are produced in the vermiculture apparatus 56 are passed to a screen 48 to be separated into coarse castings 52 and fine castings 54. Unlike the compost from the thermophilic digester, the vermiculture castings are chemically and microbially stable as soon as they emerge from the casting removal system.

The system of Fig 1 thus produces four distinct products:

1. Coarse compost
2. Fine compost
3. Coarse castings
4. Fine castings.

These may be used individually according to their suitability for particular crops or soil conditions, or may be blended to obtain properties desired for particular use. It has been found that a particularly valuable product is formed by about 90% fine compost (product 2) mixed with about 1 - 10% castings (products 3 and 4), preferably about 10%, which has greatly enhanced plant growth characteristics; it is of course possible to choose the proportion of material passing to vermiculture to optimise the process for this mixture.

Turning to the thermophilic composting process, this can be operated as a batch process. For this method, a heap of waste is placed in a container to decompose, and is aerated until the decomposition process is almost complete. The container is then emptied and refilled with a fresh heap of waste. The initial composting process occurs thermophilically. Bulking agents are used if necessary to provide an aerobic structure for active composting. The heap is structured such that air can circulate through the heap to aerate the mix naturally, and to facilitate aerobic composting.

Preferably however, the composting is operated as a continuous flow process. That is, there is continuous addition of waste to one end of the composting mass, and removal of product from the other. This method has a low energy requirement since the waste is structured to develop natural aeration. This keeps emissions, odour and costs to a minimum.

One example of a continuous process is illustrated in Fig. 2, in which a vertical system is used. An in-vessel composter comprises a modular framework 60 adapted for stacked suspension of a plurality of modular louvered containers or collars 62. Each collar 62 has dimensions of 6 m long by 5 m high by 1.2 m wide, and louvered sides 64. This modular arrangement, and the louvered sides 64 encourage free circulation of air between and within the collars 62.

Waste is fed to the collar or system of collars from a feeder 66. The apparatus further comprises means such as an auger 68 to remove treated product from the base of the collar or collars 62.

An alternative form of composter is illustrated in Fig. 3. In this form, the shredded waste is fed from a hopper 70 along a horizontal insulated tube 72. The composting waste is transported by an auger 74 which also serves to agitate and open up the material to permit thorough oxygenation. In addition, air may be blown through the tube 72. Other forms of

horizontal composter are possible. For example, a rotary tube could be used, with internal fins or paddles to agitate the material.

In use of either apparatus, shredded waste is added to the top of the collars or end of the tube. The composting material is populated by mesophilic micro-organisms which break down the cell walls of the waste particles and generate sufficient heat for a population of thermophilic micro-organisms to develop. The presence of these micro-organisms at the start of the process divides the material into thermophilic temperature zones with the temperature greatest at the start of the process, that is at the top of the heap or input end of the tube, and the micro-organisms break down the waste rapidly.

The temperature at this level is sufficiently high to kill and weed seeds or pathogens. Temperatures in excess of 70°C are attained. Keeping the material at this temperature for one hour or less should result in total pathogen kill, but we prefer to maintain such temperatures for about 24 hours or longer. Temperature monitors may be fitted to record an audit trail for confirmation of the effectiveness of the process.

The composting mix works its way downwards or along through zones of progressively lower temperature, reducing in volume over time, eventually reaching the foot of the heap or the end of the tube.

Under these conditions the microbes, bacteria and fungi introduced at the top of the heap feed on the organic matter and breed at a phenomenal rate and their huge number and activity results in a mesophilic (or 'warm') composting process. The structure of the heap ensures that an adequate air supply is drawn into each zone of the heap enabling the process optimally to develop a thermophilic or hot composition stage where the rate of organic matter decomposition is further accelerated.

Thus, this invention harnesses thermophilic composting with the use of worms for the digestion of biodegradable organic material. It is an inclusive process which has a small footprint, is mechanically simple, requires little energy input and has minimum impact on the environment. It produces a commercial range of peat alternative, compost and soil amendment products. This range of products including peat substitute, a range of mulches, good general compost, vermi-compost mixes and castings, all of which are commercially viable.

The invention enables conversion of putrescent waste into a range of useful composting products. Bioaugmentation of the waste material provides marked increase in speed of composting over known methods. The temperatures in the thermophilic stage of the process are controlled to ensure that any pathogenic organisms in the waste are killed. However, the

process of vermistabilisation also destroys pathogens. Other advantages of the invention are that no methane gas is produced, there is no leachate to damage soil, and the power, water and labour inputs required are small.

It will be understood that the invention includes within its scope (1) composting of solids combined with vermidigestion of some or all of the compost, (2) microbial digestion of liquids combined with vermidigestion of some or all of the sludge, and (3) both of these in a combined system.

CLAIMS

1. A method for processing organic waste, in which waste is treated by microbial decomposition, and at least a proportion of the resulting treated waste is further treated by vermiculture in worm bed.

2. The method of claim 1, in which at least some of the waste is treated by microbial decomposition by means of thermophilic composting.

3. The method of claim 2, in which the thermophilic composting subjects the material being composted to a temperature of at least 70°C for a period of at least one hour.

4. The method of claim 3, in which the temperature of 70°C is maintained for 24 hours,

5. The method of any preceding claim, in which the waste consists of or includes liquid waste which is treated by microbial decomposition by means of aerobic or anaerobic digestion to produce a clarified liquid and a sludge, some or all of the sludge then being treated by vermiculture.

6. The method of claim 5, in which the liquid waste undergoes a preliminary step of moisture modification to separate it into a liquid part which is then treated by digestion and a solid part which is treated by thermophilic composting.

7. The method of any preceding claim, in which material to be composted is first shredded.

8. The method of claim 7, in which the shredding step is also used to mix together a number of incoming waste streams.

9. The method of any of claims 2 to 4, in which the compost produced by thermophilic composting is separated into coarse and fine fractions, and a selected proportion of the fine fraction is passed to vermiculture.

10. The method of claim 9, in which said selected proportion is passed to vermiculture substantially immediately, while the remainder of the fine fraction and the coarse fraction are cured by aerobic storage.

11. The method of any preceding claim, in which both microbial decomposition and vermiculture are carried on as continuous processes.

12. Compost produced by the method of any preceding claim.

13. Compost according to claim 12 which comprises fine compost and includes 1 - 10% worm castings.

14. Apparatus for processing waste comprising microbial decomposition means for receiving waste and producing microbial decomposition therein,

vermiculture means receiving organic material and supporting a population of worms feeding upon said material to produce castings, and transfer means for transferring a selected proportion of treated material from the microbial decomposition means to the vermiculture means.

15. Apparatus according to claim 14, in which the microbial decomposition means comprises a thermophilic composting system.

16. Apparatus according to claim 14 or claim 15, in which the microbial decomposition means comprises an aerobic or anaerobic digester for liquid waste.

17. Apparatus according to claim 16, including moisture modification means for separating incoming liquid waste into a liquid stream and a solid stream.

18. Apparatus according to claim 15, including means for shredding and mixing together a plurality of incoming streams of solid waste, and means for passing the shredded and mixed waste to the thermophilic composting system.

19. Apparatus according to claim 15 or claim 18, including a screen arranged to receive compost from the composting system to separate the compost into a coarse fraction and a fine fraction and to pass the fine fraction to the vermiculture means.

20. Apparatus according to claim 19, including a shredder interposed between the screen and the vermiculture means.

21. Apparatus according to any of claims 14 to 20, in which the vermiculture means is a vermiculture machine comprising a housing, a grating within the housing supporting a worm bed, and means for controlling environmental conditions within the housing.

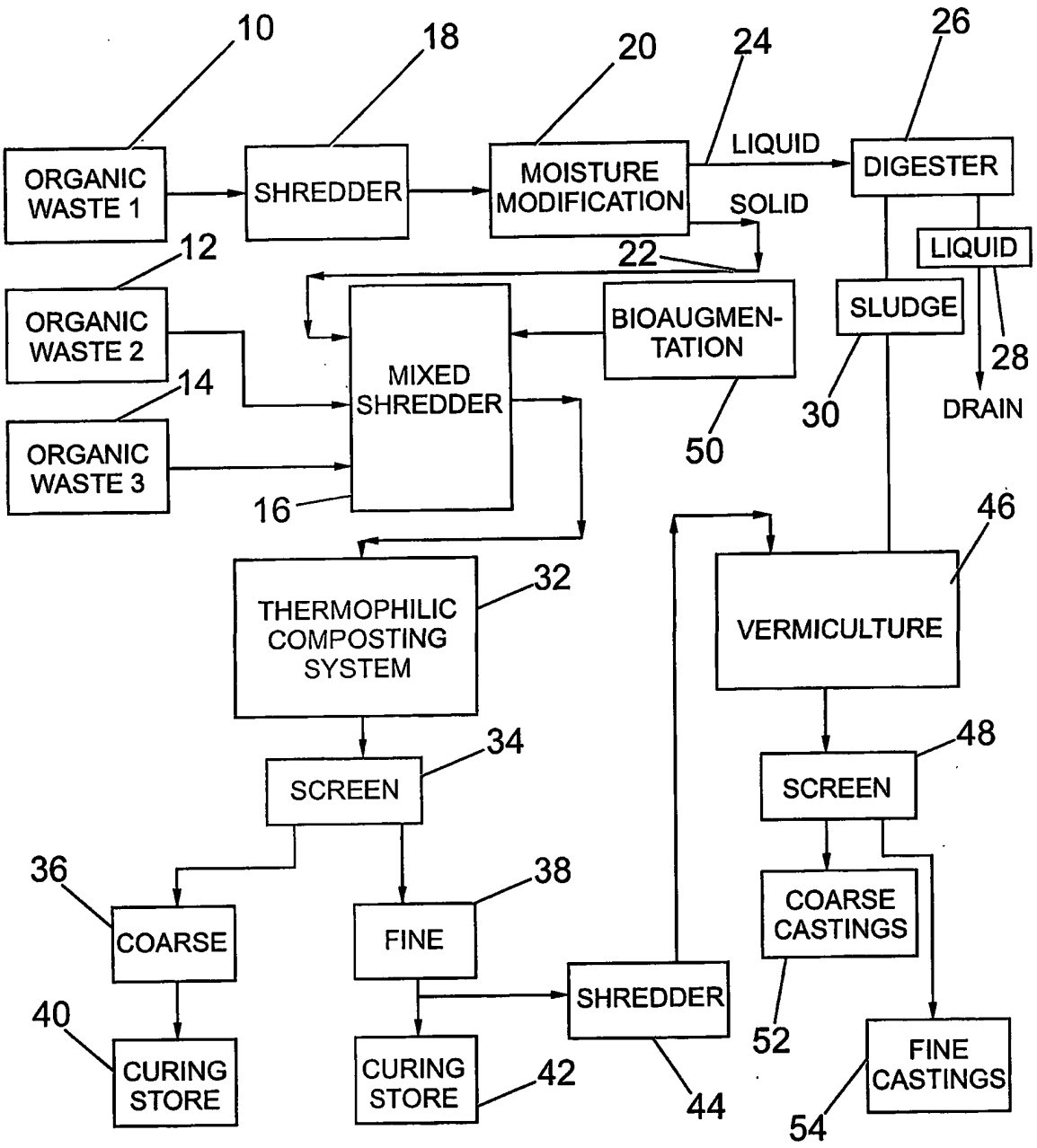
10
18
20
24
26
ORGANIC WASTE 1
SHREDDER
MOISTURE MODIFICATION
LIQUID
DIGESTER
SOLID
LIQUID
12
22
ORGANIC WASTE 2
MIXED SHREDDER
BIOAUGMEN-TATION
SLUDGE
28
14
30
DRAIN
ORGANIC WASTE 3
50
16
46
32
THERMOPHILIC COMPOSTING SYSTEM
VERMICULTURE
34
48
SCREEN
SCREEN
36
38
COARSE
FINE
COARSE CASTINGS
SHREDDER
40
52
CURING STORE
CURING STORE
42
FINE CASTINGS
44
54

Fig. 1

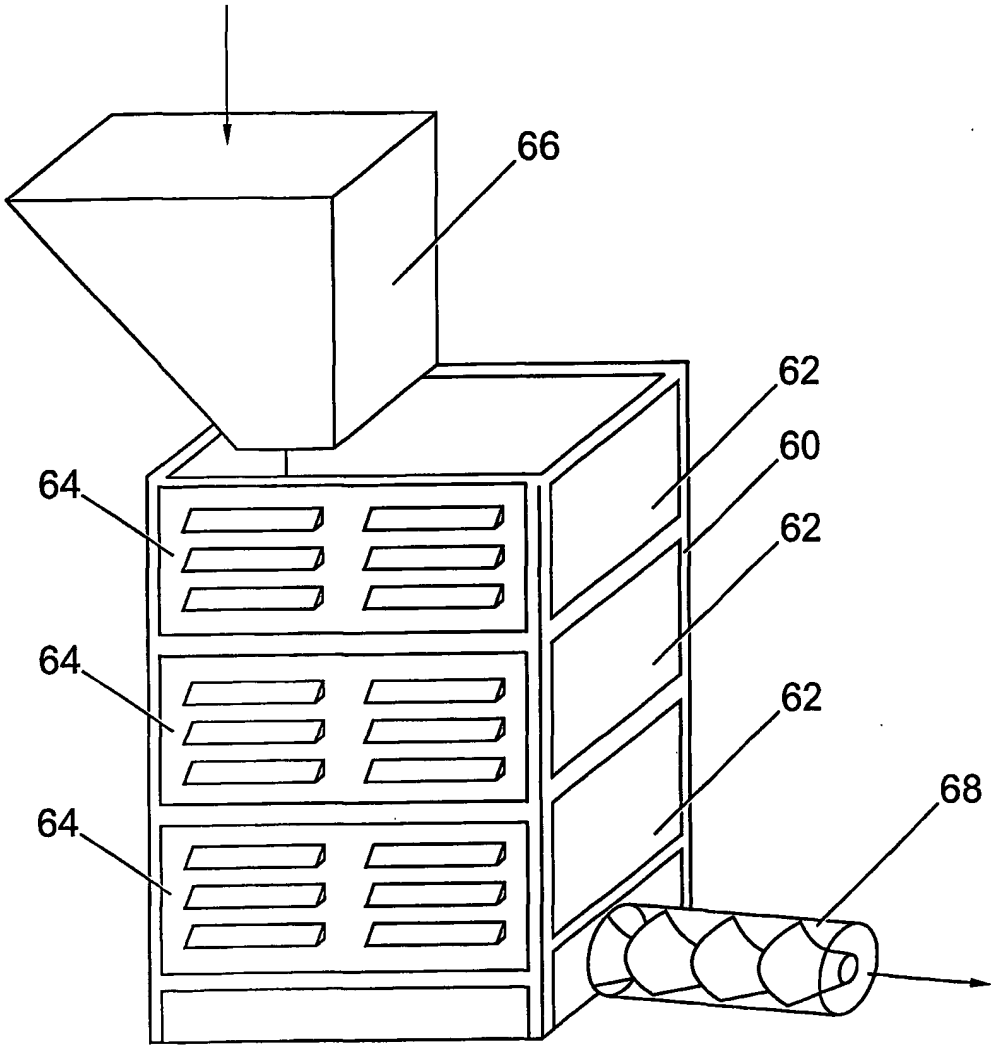

Fig. 2

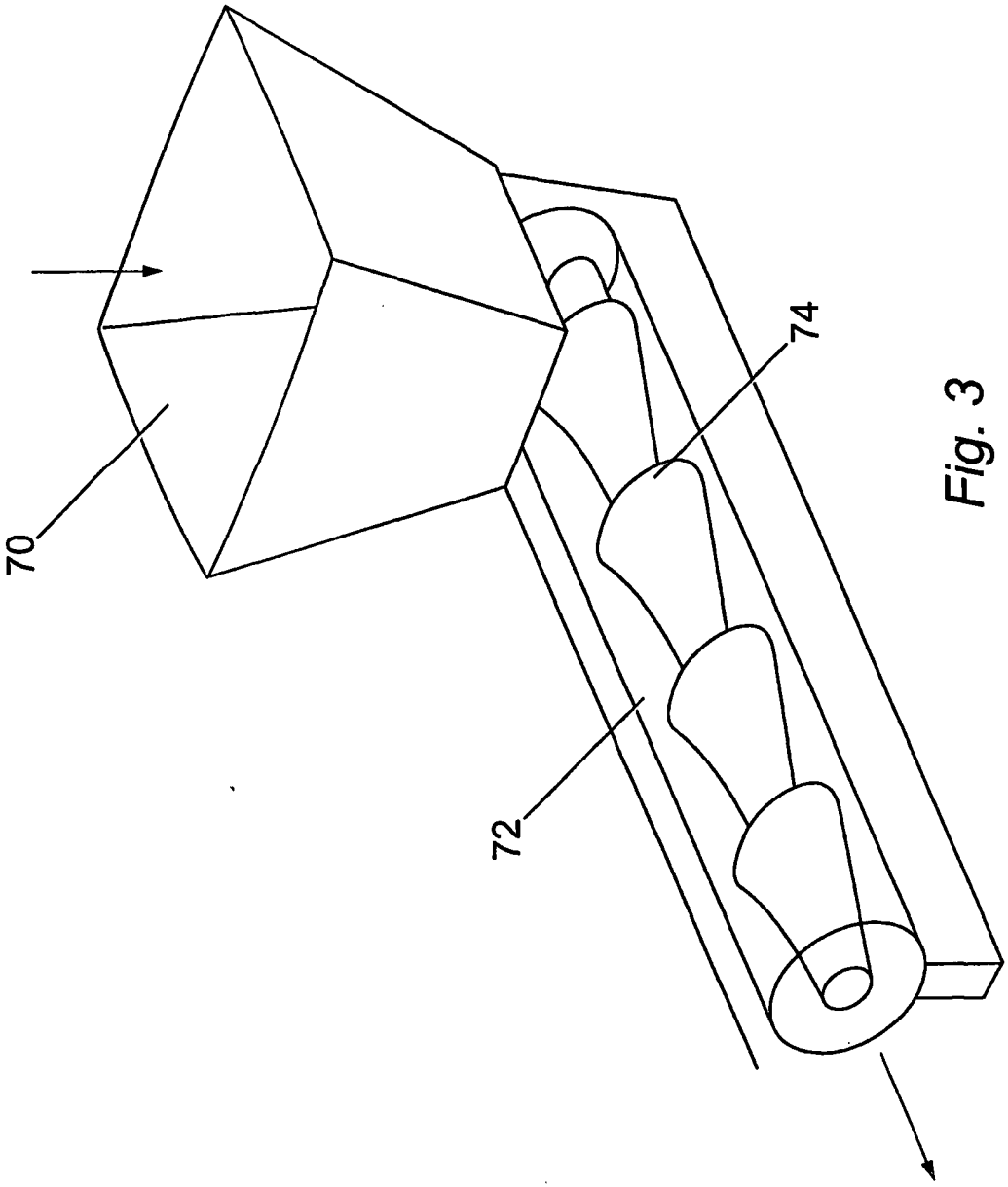

Fig. 3

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(74) Agent: **PACITTI, Paolo**; Murgitroyd & Company, 373 Scotland Street, Glasgow G3 8QA (GB).

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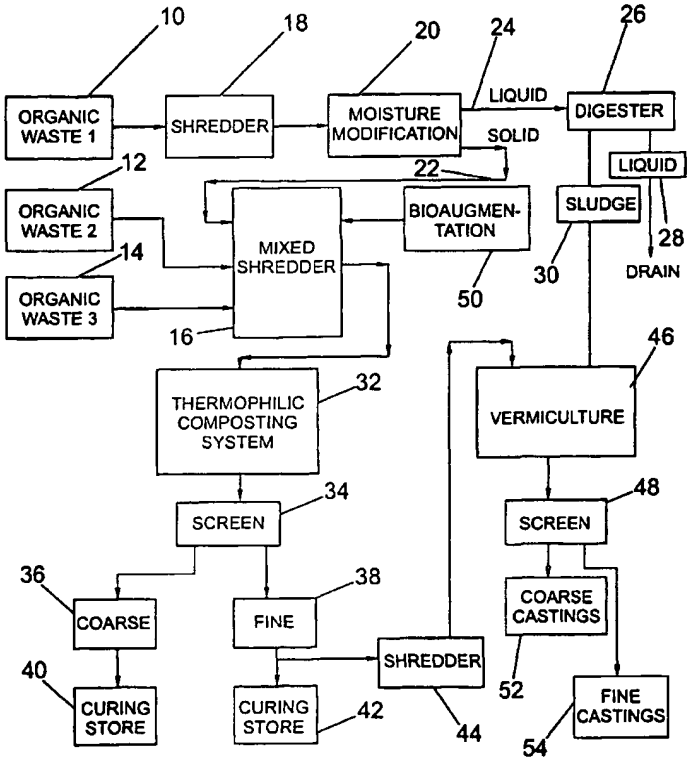

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Minimum documentation searched (classification system followed by classification symbols)
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 6 124 112 A (J. MOLENAAR) 26 September 2000 (2000-09-26) column 2, line 55 -column 3, line 18; claims	1-20 21
X Y	WO 97 10190 A (ACT DEPARTMENT OF URBAN SERVICES) 20 March 1997 (1997-03-20) page 6, line 4 -page 7, line 30; figure 3	1,2,7,8, 12-15 2-6, 9-11,16, 17,19,21
Y	CA 2 170 294 A (A.B. EGGEN) 27 August 1997 (1997-08-27) cited in the application claims; figures	21

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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Form PCT/ISA/210 (second sheet) (July 1992)

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	CHEMICAL ABSTRACTS, vol. 133, no. 14, 2 October 2000 (2000-10-02) Columbus, Ohio, US; abstract no. 192617r, G. MASCIANDARO ET AL.: ""In situ" vermicomposting of biological sludges and impacts on soil quality" page 640; XP001039485 abstract & SOIL BIOL. BIOCHEM., vol. 32, no. 7, 2000, pages 1015-1024,	5,6,16, 17
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